

REQUIREMENTS GENERATION SYSTEM

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ABSTRACT

The Requirement Generation System (RGS) is a computer supported cooperative work (CSCW) tool that provides an interactive processing environment to define, control and structure mission requirements. RGS reduces the time and cost of developing requirements by automating many of the activities associated with the development, editing, review, approval and creation of requirements documents. Users can view requirements, import on-line document files, copy text from on-line documentation into requirements definitions, browse parent documents and requirements, and also generate user-tailored reports. RGS was developed using a client/server architecture. All user activities take place on the client machines and all data is stored on a centralized server. This allows geographically dispersed users to concurrently access parts of a document for reading, creating, modifying, or creating notes/comments about requirements for others to read. Requirements once written can be submitted for approval and once approved are automatically included into a final requirements document. RGS provides traceability by linking requirements and other documents together. RGS is also highly configurable so that it can be used to support different requirements development processes.

1. INTRODUCTION

One of the most important and time-consuming tasks for any mission is the development of mission requirements. The Requirements Generation System (RGS) is a computer supported cooperative work (CSCW) tool that provides an interactive processing environment to develop mission requirements. RGS reduces the time and cost of developing requirements by automating many of the activities associated with the writing, editing, review, approval and creation of requirements documents.

RGS was developed to provide:

- requirement analysts/authors with a system for capturing, entering, controlling, collaborating on, and validating mission requirements,
- mission managers and other personnel with requirements and documentation tracking information pertinent to an individual requirement,
- mission data system managers with an automated means of viewing and responding to individual requirements and
- a historical database of project requirements for future planning purposes.

In RGS users can define and view requirements, import on-line document files, copy text from on-line documentation into requirements definitions, browse parent documents and requirements, and also generate user-tailored reports. RGS supports the approval process by allowing designated mission personnel to reject requirements or accept them for inclusion into a requirements document. RGS also provides those in charge of implementation of requirements with an automated means of viewing and responding to individual requirements.

RGS supports traceability by allowing users to link requirements to parent documents, functional areas, and/or other requirements. Configuration management is also available to easily back out changes and a historical database to promote reuse of requirements across missions. The RGS database is available to all mission personnel throughout the life cycle of the mission, thus facilitating the communication of information about all levels of mission requirements.

The remainder of this paper describes the underlying system, user interface and costs savings that have resulted from NASA missions that have used RGS.

2. SYSTEM DESCRIPTION

The following sections describe how requirements are managed within RGS, user privileges, requirement hierarchies, on-line approval/rejection, requirement status, document production, configurability and working groups.

Information Management

RGS is implemented as a distributed client/server database system that supports cooperative work among geographically dispersed users. RGS data is stored and managed using a relational database management system (Sybase) operating on a back-end server. All user activities, such as requirements entry and report generation, take place on the client machines. This allows different users to concurrently access different parts of a document.

All levels of requirements and all requirements documents, commentary and rationale are consolidated in a single database, reducing the time needed to locate, review and disseminate information. This eliminates the need for traceability across separate databases and allows for the production of reports that contain requirements at varying levels of detail. RGS also provides, within the single database, additional aids to communication between mission personnel. Requirements may be associated with keywords and elements to help identify and group requirements. Requirements may be flagged for printing, for re-evaluation and to generate change-bars. In addition, users may enter notes against a requirement or a group of requirements, allowing for comments or suggestions as requirements are development.

RGS maintains a history for each requirement. Requirement histories include the date and time any action is taken on the requirement, and the person who performed the action. Histories reveal not only recent actions taken on a given requirement, but overall statistics as to use of the system and stability of the requirements in general.

Additional documents may be provided within RGS for reference and explicit traceability to requirements in parent documents. Parent documents are not developed within RGS, but may be entered into the system by the mission manager or designated personnel. While they are not included in the browser hierarchy, the mission's requirements may be explicitly linked to the appropriate part of the parent document, thereby

providing specific traceability from the requirements to parent documents. In addition, RGS will perform services to ensure that there is complete traceability from a parent document into a mission's requirements.

User Privileges

RGS provides configurable user privileges. Differing user privileges provide security for requirement data, while allowing a wide range of users to benefit from requirement information. Some of the supported user privileges are: read-only, requirements developer, approver/responder and mission manager.

The read-only privilege allows access to requirements by people who are not requirement developers. Read-only users are allowed to browse and search, and report on requirements and their histories, approvals and notes but they may not make any changes. Read-only users can also be given the privilege of composing and attaching notes to requirements.

Requirements developers can define, control and structure mission requirements. Depending on mission configuration, developers may generate requirements on-line, and/or import requirements; provide traceability by linking requirements to parent documents, functional areas, and/or other requirements; associate requirements with keywords; and create notes on-line for specific requirements.

Approvers and responders may accept or reject requirements for inclusion in the official requirements document as well as enter a rationale for their decision. They may also create and edit responses to mission requirements. These responses, if accepted, are included in the requirements document. If allowed, they may also accept requirement responses, allowing them to also be included in the requirements document.

Mission managers manage much of a RGS Database. They may be assigned the privileges to edit the structure of the requirements document, create keywords and/or element IDs (that may then be assigned to requirements), enter parent/reference documents and define levels.

Requirement Hierarchy and Levels

All levels of requirements are presented to users in a hierarchical "browser" format, giving mission personnel an overall view of the state of the requirements document and the hierarchical relationship between various levels of requirements. Each requirement in a given section is identified by a "label" in the form <xxx.xxx...xxx>, which determines its placement in the browser hierarchy. Figure 1 shows a sample hierarchy. In this example, the first requirement in section 4100 would be numbered 1 (or 4100-1), with its subordinate requirements numbered 1.1, then 1.1.1, and 1.2, etc. A requirement's placement in the hierarchy indicates dependent relationships between requirements in a given section at a glance.

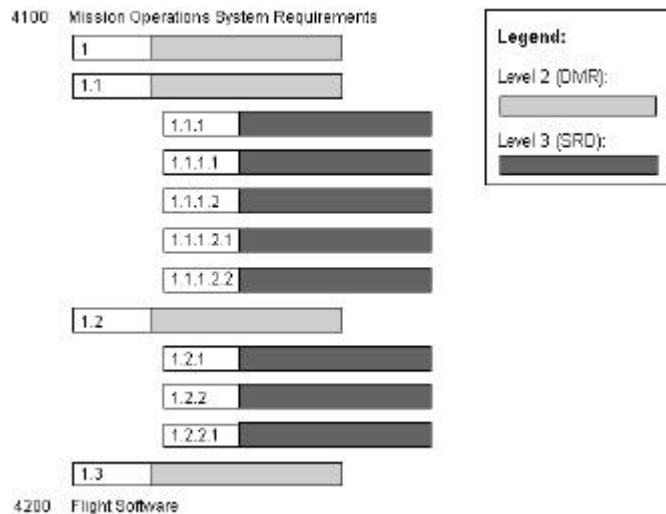


Figure 1: Sample requirement hierarchy and relationship between levels and hierarchy.

Each requirement entered in RGS is also assigned a "level", which associates the requirement with a given level of detail for a given document. The requirement level is independent of the hierarchical number assigned to the individual requirements. Each mission may determine the relationship between the levels and the hierarchy for that mission. For example, a given mission may decide that requirements from the third decimal point down be assigned to Level 3, and requirements higher in the hierarchy to Level 2, as illustrated in Figure 1.

On-line Approval/Rejection.

Requirements once written can be submitted for approval and once approved will automatically be included into the final requirements document. RGS provides on-line, form-based capabilities for approving or rejecting a requirement and attachment of rationale for a decision. Reviewers can also attach on-line "notes" for commenting on individual requirements. These notes are then available to all users.

Approval privileges for a specific level of requirement may be assigned to any of the user types. For example, for detailed-level requirements, approval could be assigned to only the mission manager; to the mission manager and data systems manager; or any other combination of users. Different users may be assigned approval privileges for different sections of requirements as appropriate. These users may view the requirements and respond either positively, negatively, or conditionally.

Requirement Status

RGS assigns each mission requirement in the database with a "status" that describes how far the requirement has progressed toward final approval. A status can be private, draft, pending, in-review, accepted, rejected or accepted with contingencies. A private requirement is one that is work in progress, visible only to the author or working group. A draft requirement is work in progress, visible to anyone with access to the mission. A pending requirement has been submitted (but not yet accepted) for approval. An in-review requirement has been accepted by some, but not all approvers. An accepted requirement has been accepted by all parties responsible for its approval.

A rejected requirement has been rejected by at least one of the approvers. An accepted with contingencies requirement that has been accepted by all approvers, but to which the mission manager has responded with exceptions.

There are several advantages to having a status for each requirement. The instant availability of newly-developed requirements (i.e., draft or pending) provides access to the current thinking on issues and allows for speedier review and response from interested parties. Further, approving requirements individually (as opposed to waiting for the release of a set of requirements in a document) can speed up planning and design. Finally, the overall view of the status of the requirements aids management in their assessment of the progress that has been made at any point in time. Inadequate requirements in a certain mission area can be identified, and measures can be taken to correct any difficulties occurring with the development of the requirements.

Document Production

RGS provides a wide range of reporting capabilities, including standard system reports, "print screen" options, customized reports and NASA Detailed Mission Requirements (DMR) formatted reports. The document format may also be customized to adhere to other formats (such as System Requirements Document (SRD) or non-Goddard document formats). Reports may be printed, or saved to an ASCII text file for use with other word-processing applications. Reports also may be exported in a tab-delimited format, allowing for use with standard spreadsheet software.

Report contents can be defined by users using a simple selection technique. RGS allows the user to determine which sections, levels and requirements will be included in the document (e.g., only accepted Level 2 requirements for Sections 2000 and 3000). The document can then be exported to Microsoft Word, and any desired formatting changes may be made using Word's word processing capabilities. Documents and reports can also be produced for any or all levels of requirements and for requirements assigned to any combination of organizational elements.

Configurability

RGS is also configurable on a per-mission basis to meet the needs of different processes. Because different missions have varying needs, RGS allows a Mission Administrator to define mission-specific user types and acceptance privileges. At the beginning of a mission RGS may be configured to customize:

- any number of mission-specific user types (e.g., a requirements developer, mission manager, data systems manager, read-only user, etc.), with unique privilege assignments.
- mission-specific levels (allowing for a greater detail beyond the standard three levels)
- a mission-specific structure for a requirements document
- mission-specific acceptance privileges (determining what approvals are necessary for what sections and levels of requirements).

Working Groups

In an effort to encourage cooperative work between mission personnel, RGS allows each mission to set up "Working Groups," and assign mission personnel to these groups. Working Groups allow more than one user to work on a given requirement. The Working Group is considered to be the "author" of its requirements. Any member of a given working group has full write-access to that group's requirements, while users not in a given working group are prohibited from editing that group's requirements. Any member of the requirement's working group may also submit the requirement for approval.

Configuration Management

RGS also supports a structure configuration management (CM) capability for controlling and approving changes to a mission's requirements. These features are typically disabled in the initial requirements definition phases and are then invoked after approval of a mission's baseline requirements. The features include: establishing a configuration control board who will approve, above and beyond the normal approvers, any changes to a mission; ability to specify which control board members are likely to be affected by a modified requirement; and the ability to take "snapshots" of a mission had then later be able to track and compare changes to the mission's requirements since a "snapshot" was made.

3. RGS USER INTERFACE

The RGS user interface runs on Macintosh computers and PCs running Microsoft Windows (Windows 3.1 and 3.1.1, NT and Windows 95). There is no difference in the functionality between the PC and Mac platforms and the only difference in appearance are those appropriate to the "look-and-feel" of the different operating systems. When RGS is first initiated, the user is given a login screen and a list of missions to select from. Once logged on a user can create, edit, browse, search, import, export, review, annotate, approve or print requirements. The entire user interface has too many windows to present here. Instead, only a few of the windows will be shown to give a flavor of how RGS looks and operates. A web-based viewer is also available for users who only want to read and not modify requirements. This allows users to access the RGS without having to install client-server software on each of the desktop computers, except a web browser like Netscape.

Requirements Browser

The RGS Requirements Browser provides an overall view of the requirements in the database, organized by chapters (called functional categories) and sections (Figure 2). The browser provides a "Big Picture" view of the document outline and the requirements that have been entered. When the browser first appears it display only the list of sections assigned to the selected functional category. A user may browse requirements by expanding and contracting the section folders to display requirement lists and switching functional categories to access new sections. Functional categories can be changed by selecting the drop down menu at the top of the browser and sections can be expanded by double clicking on the folder icons.

A filter is also available to limit the information that appears in the browser, so that only the requirements a user needs to see will be displayed. Requirements may be filtered by sections, functional categories, levels and print flags. Searching can also be used to generate a list of requirements tailored to a user's particular needs. Users may search on functional category, section, label, RGS ID, status, response, snapshots, working group, author, level, date entered, data last modified, title and many other attributes. Reports can also be generated on the search results.

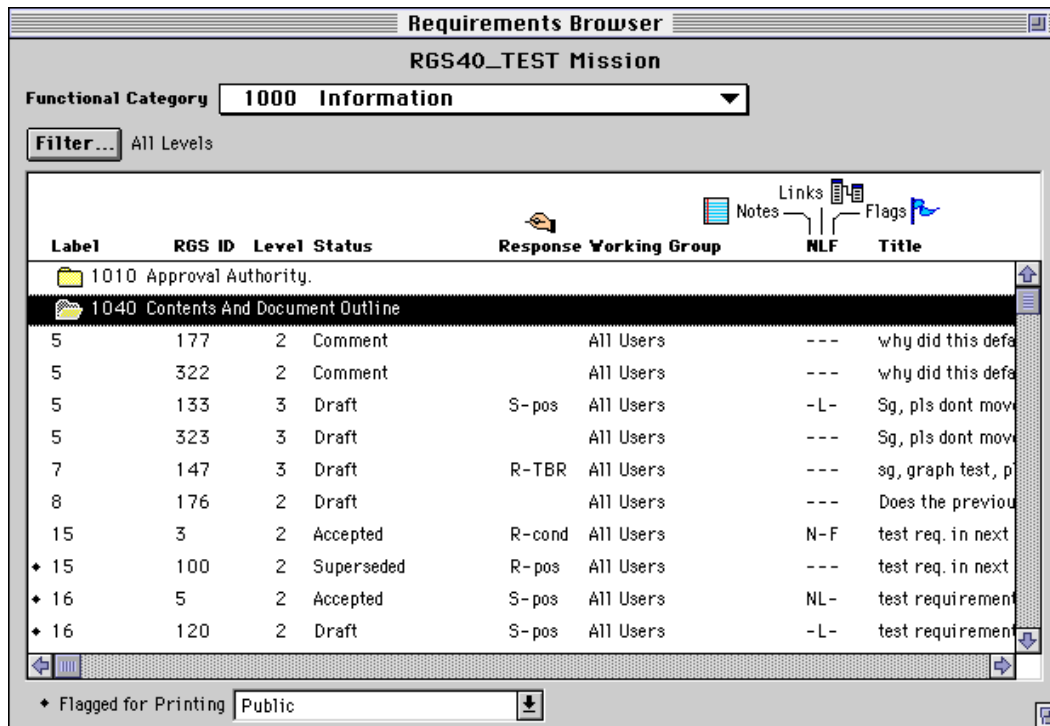


Figure 2: The Requirements Browser window.

Requirements Details Window

RGS provides a form-based graphical user interface for entering and editing requirements on-line (Figure 3). Requirements may be entered in any order. They are numbered by the requirements developer as they are entered, establishing their placement in the requirement hierarchy.

Requirements are entered, edited and viewed through the requirements detail window, as shown in Figure 4. From this window notes, links, flags, keywords, elements and snapshots can be viewed or defined. Requirements may be made up of one or more items, which can be text, graphics or tables. An example of a graphic for a requirement is shown in Figure 4. When new requirement is being defined, a window is opened, similar to the one in Figure 3, that is empty and can be filled in by the developer. Developers may also enter non-requirement annotation at any position in the hierarchy to serve as introductory, informational and/or concluding text. The annotations are entered in a form very similar to requirements, and may also include text fields, graphics and/or tables.

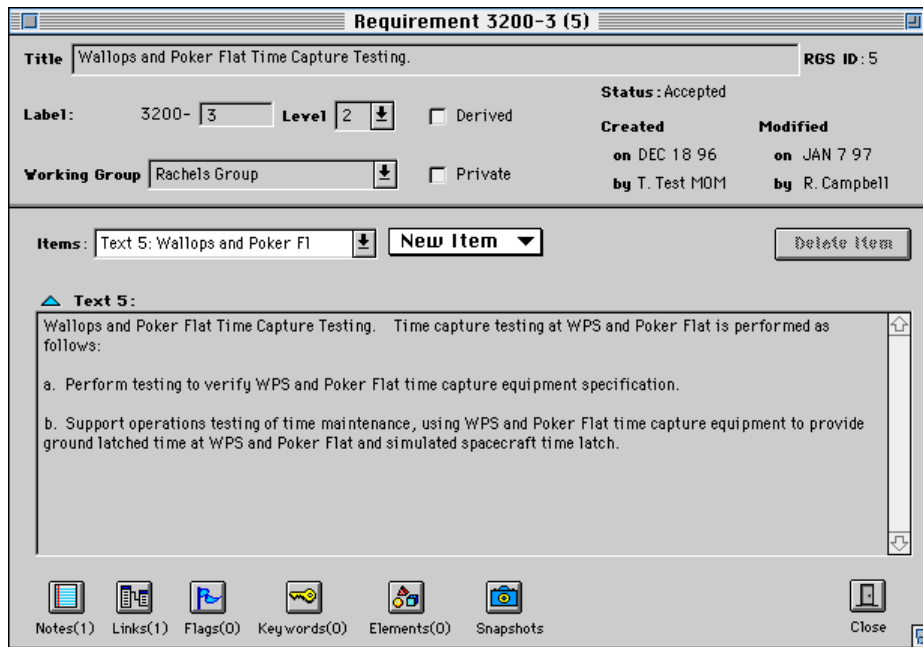


Figure 3: The Requirement Details window.

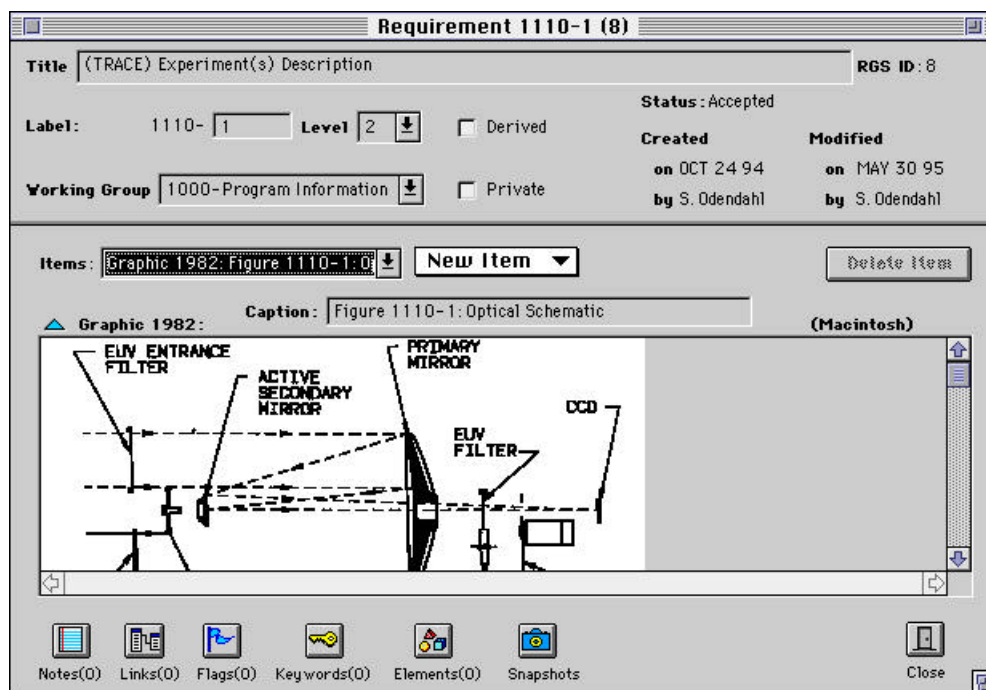


Figure 4: The requirement detail window containing a graphic.

COST SAVINGS USING RGS

A report for Code 510 at Goddard Space Flight Center was written that included the time it took to develop requirements on several missions [1]. It was found that time for developing requirements was dramatically reduced when using RGS (Figure 5). They noted that "... despite ACE having lower reuse than TRMM and FAST and despite ACE having a more complex system than SAMPEX, FAST, SWAS, the manpower needed by ACE to gather requirements was lower than SAMPEX, FAST, SWAS, XTE and TRMM. This was accomplished by the addition of a tool, the Requirements Generation System (RGS), an on-line requirements database, which could be accessed by all team members and a process change to gathering requirements." TRACE and WIRE also used RGS. It was further noted that RGS alone did not lower the cost, but was the enabling technology for a new process. This process and RGS allowed greater communication during the develop of requirements and reduced the time spent approving the requirements and in meetings.

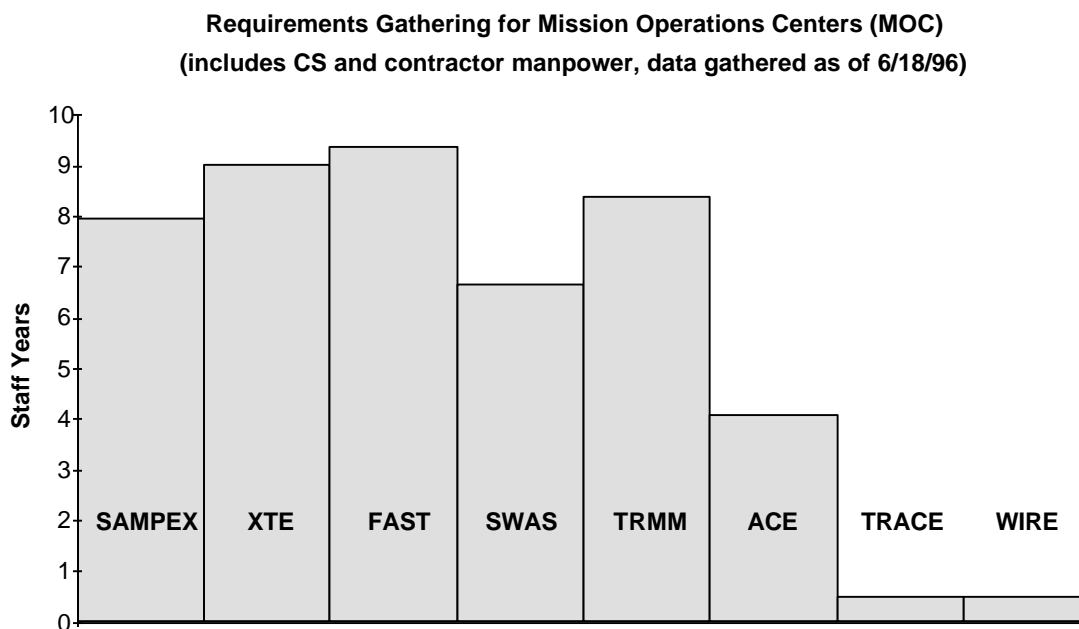


Figure 5: Time savings in developing requirements for missions that used RGS.

CONCLUSION

RGS is currently at version 4.0 and is a very stable product of commercial quality. It has been used on 32 projects in the past four years, including ACE, IFMP, TRACE, WIRE, EOS AM1 and several Hitchhiker missions where it has helped to reduce the cost of developing requirements. Several other tools that complement RGS are also under development or are planned. One tool under development is a test tracking tool that links tests in its database to requirements in the RGS database. Future plans include allowing other tools to link into the RGS database and adding work-flow support. This will allow better communication between developers and will also provide better support to NASA and other development processes by allowing user actions or events to trigger other actions, such as sending email to inform someone a requirement has been accepted or rejected.

REFERENCES

[1] Mandl, D., Coyle, S., Rashkin, R., Langston, J., Karlin, J. and Welch, D. 1996. Overcoming MO&DSD's Learning Disability to Building Ground Data Systems "Faster, Better, Cheaper". Internal NASA Goddard Space Center Paper.